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Rockfall Hazard and Risk Assessment along Aizawl-Durtlang Road Section, Mizoram, India

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Abstract

Aizawl is growing in an anticline where Middle Bhuban rocks are found be present along ridge which show high topographic slope on both sides of the axis. The elevation difference, high slope variability, variable rock strength and litho-association are important factors in the stability of the rock beds around the region. The area is susceptible to many landslides and some of them are also subjected to rockfall events. Most common rockfall event have been observed in Aizawl Durtlang road section. In this area vulnerability study has not been done to such an extent and therefore hazard assessment was required to understand the hazardous localities. The area is subjected to rockfall events rather than other sliding mechanisms occurred in other areas. The

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geologic map and profile along the road section indicate sandstone dominating arenaceous lithounits are present with interbedded shale and siltstone. The structural attributes and other thematic maps indicate that the most of the sections are favourable for rockfall events. The stereoplots for the joint surfaces also reveal that the area is also susceptible to wedge failure, that again lead to rockfall events. This study also reveals that activities like slope cutting or building construction without any adequate measures can lead to such a catastrophic event in the area.

Keywords : *Aizawl, Rockfall, Landslides.*

Introduction

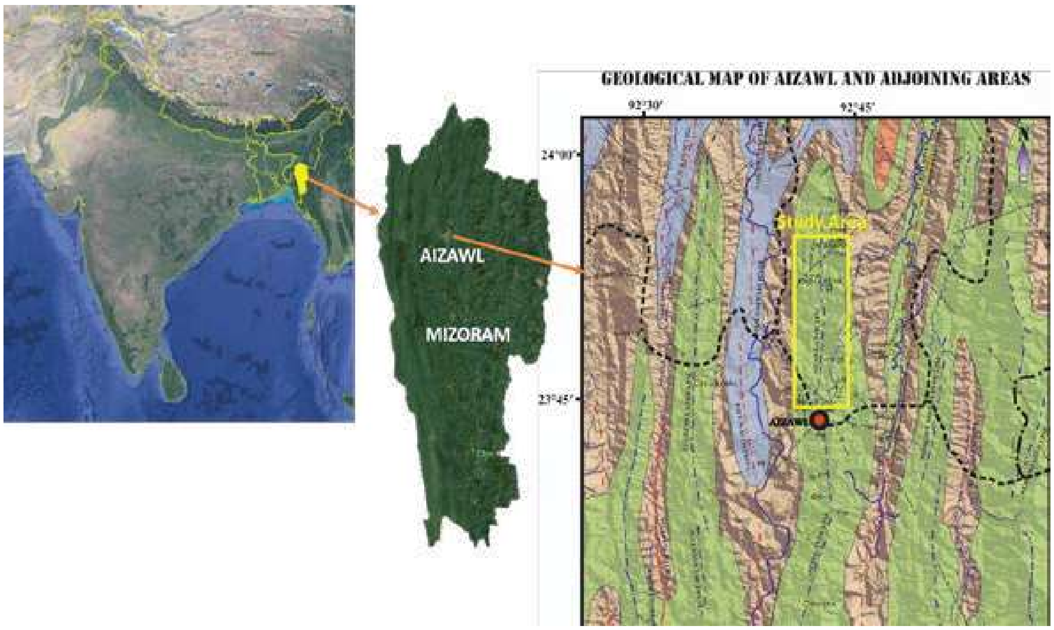
Landslides and rockfalls are one of the most devastating and sudden natural calamity that cause destruction of life and property (Keefer 1984; Guzzetti et al., 2003; Keskin 2013). When a rock block formed by the intersection of the joints and if kinematics help to detach from the slope then Rockfall might be initiated by planer or wedge failure (Sepulveda et al., 2005; Mavrouli et al., 2009). Rockfalls can be associated with earthquake, neotectonic activities, temperature variations and rainfall (Asteriou et al., 2012; Dorren 2003).

The rock association present in the Aizawl city comprise of Bhuban Formation rocks of Surma Group. Basically, the Group has been classified into Bhuban and Bokabil Formation based on their textural and sedimentological characteristics. The overall thickness attains about 5000 meters in the region. Bhuban

Formations comprises of three Member subdivided as Upper, Middle and Lower Bhuban units; among which Middle Bhuban rocks are exposed all along the Aizawl ridge (Fig 1). This unit comprises of repetition of arenaceous and argillaceous rock units with inter-bedded sandstone, siltstone and shale (Tiwari and Kachhara, 2003). Sedimentary structure like ripple marks, current building etc., are observed in these litho-units.

Aizawl is situated in an anticline of the Mizoram fold belt where the beds are dipping towards East and West of the north-south trending ridge. The topographic relief, bedding conditions, high precipitation and anthropogenic causes create many type of landslides in the area. In numerous landslides occurred around Aizawl during 2015-16, affects about 700 sq km of area that results in damaging more than hundreds of households and even cause some casualties (Chenkual, 2015). In Aizawl, landslides were occurred mostly due to high slope and relief, active tectonic setting of the region, heavy rainfall and unplanned land use practices that continues in the region for long. There mostly three types of landslides around Aizawl; one associated with translational slide that occurred in Hlimen and Laipuitlang area of Aizawl; second associated with rotational slide surfaces that result in landslides of Hlimen and Rangvamual localities. The third and comparatively less studied is the rock falls that cause much damage in last few years. One such locality is the Aizawl-Durtlang road section, where rockfall incidents are very common and it is one of the highest elevated region around the city. In the study the potential rock fall zones are identified to build a safer Aizawl.

Figure 1: Geological Map around the study area (yellow rectangle) comprising Middle Bhuban rocks along the ridge section (Modified after Rakshit et al., 2017).



Methodology

The geological map and cross-section were prepared from the data recorded during extensive field study carried out along the road section. The bed attributes are recorded and plotted in different softwares to produce adequate results to understand the possibilities of the rock fall events. The geologic map and profile was constructed by Global Mapper 18 software. The stereoplot was drawn in Stereonet 9.8 software (Allmendinger et. al., 2012; Cardozo and Allmendinger, 2013). The Topographic, Slope, Slope Direction, Stream Pattern, Rock Strength and Risk Assessment Thematic maps were prepared by different features of Global Mapper and Google Earth softwares. Rock strength was measured with the help of in-situ geotechnical techniques.

Results and Discussion`

The geological map and cross section of the study area infers that the road section is comprised mainly of sandstone and shale dominated part, with some siltstone beds were also observed (Fig. 2). The dipping of the beds is mostly intermediate to high dip angle with slope towards western side of the ridge. The interbedded layers of the eastern part of the ridge comprise of the beds dipping in the same direction that with the topographic relief. This unstable bedding conditions results in failure along the slip surfaces (Rodgers and Tobin, 2014). Whereas in the western part as observed in our study, joints and fractures in the similar bedding conditions with greater topographic slope increase the possibilities of rock fall in the hard and compacted litho-units. The reason behind such fall is the wedge failure and toppled down due to adverse bedding situation. The Aizawl- Durtlang road section is subjected to this condition and therefore suffers more rockfall events than sliding along the planes. Further disturbances occurred in the slope condition due to various anthropogenic causes like excavation on the slope side, unplanned settlements, poor drainage system, deforestation, used water disposal and improper water supply and sewage systems enhanced the vulnerability (Chenkual, 2015). These lead to the weathering of the rocks and transforming them to soil and regolith. Soils formed in this way are loose sedimentary type, with high porosity and permeability in them. With high precipitation and even higher surface runoff results in precipitation induced landslides and rockfall (SIPMIU, 2011).

Figure 2: Geological map and profile of the Aizawl-Durtlang road section.

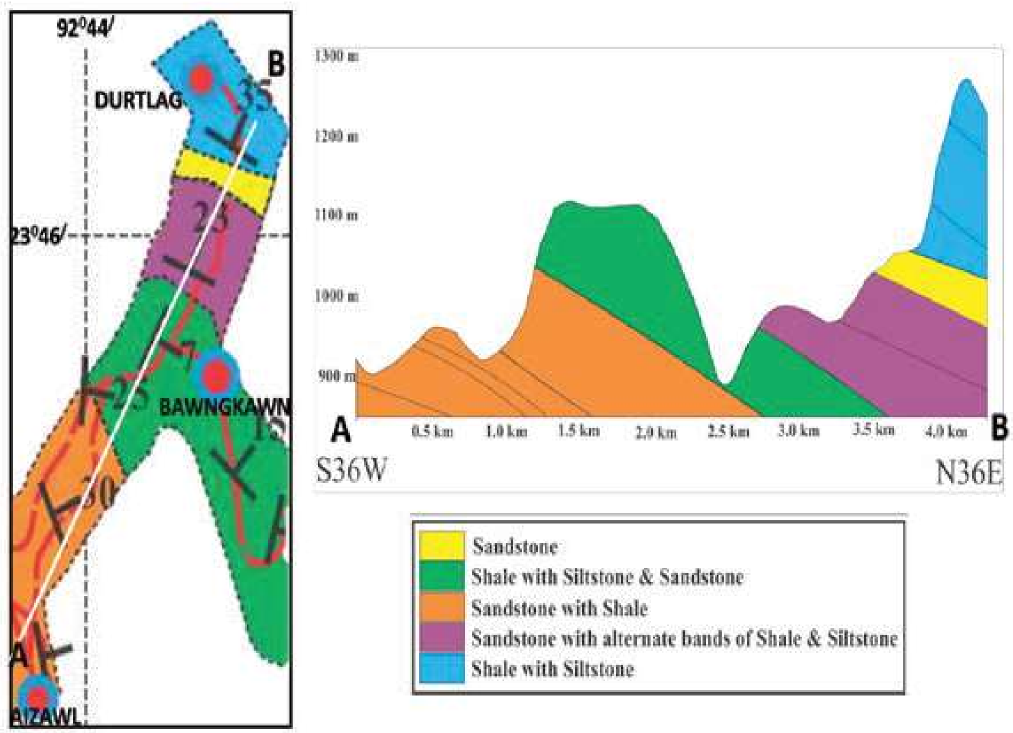
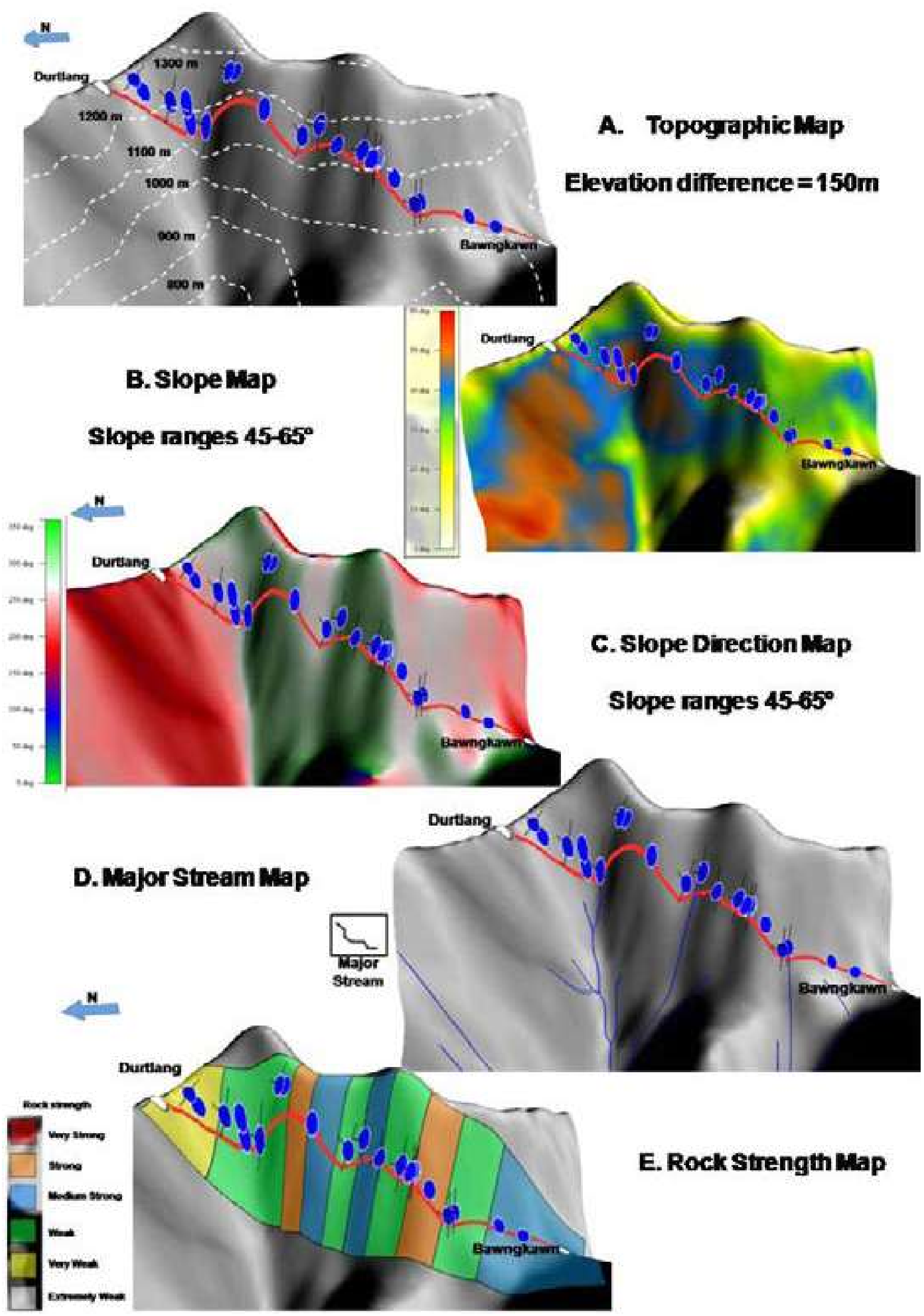


Figure 3: Different Thematic Maps for the Aizawl-Durtlang Road section. (Blue dots are some of the sample points along the bed attributes for that location).

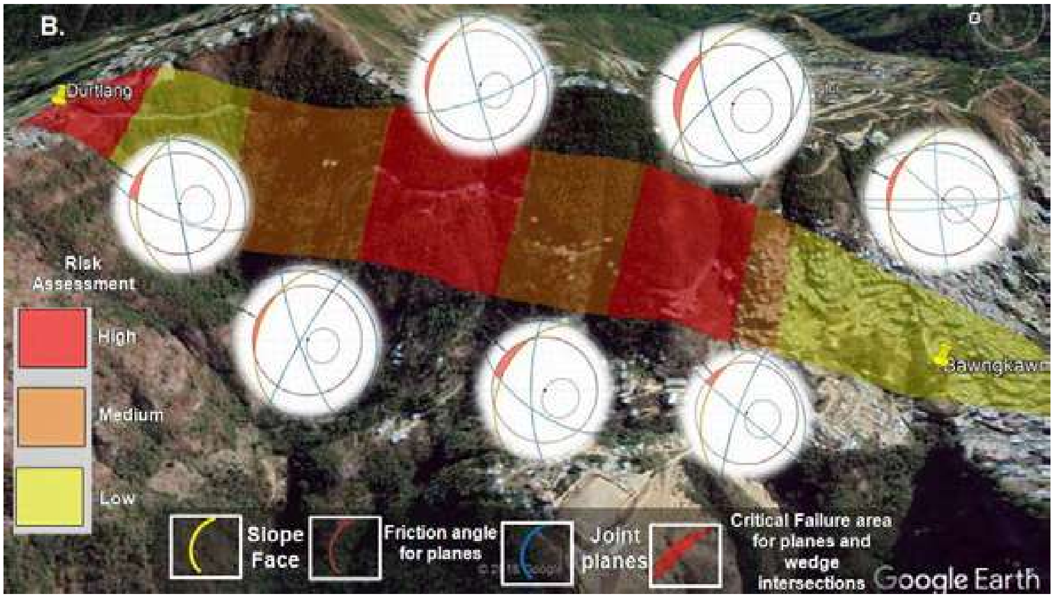


To understand and assess the hazard condition in the road section, different thematic maps in GIS format are essential. These could only help to distinguish risk zone from the comparatively safer ones around real scenario. The average elevation differences in for the road is found to be around 150m (Fig. 3A). The topographic slope of 65° to 75°, as observed in the study area, could create more vulnerable situation to the already unstable condition (Fig. 3B). In such slope, average of 2.5m of soil were also observed during the field study. In some places, the loose soil is underlain by other soil type (blackish or reddish in colour) or rock beds were exposed (GID, 2007). The rock beds are mainly composed of sandstone and sandstone-siltstone association with shale beds are present in between. In other cases, shale dominating argillaceous facies also cause dismantling the arenaceous beds from the outcrop. In addition to that, slope direction also favours the sliding conditions along joint sets rather than the bedding surface (Fig. 3C). In this road section, the structural attributes are found to be similar as this part of the study area comprised the same ridge zone. The strike of the beds is from N30°W-S30°E to N40°W-S40°E with dip varies from 12-38° dipping towards 20°-30° NE. The joint sets observed in some points of the study area have trends towards EW to N38°W. The DEM has been used to identify the areas where the topographic slopes are geotechnically unfavourable due to water inflow along the major stream patterns (Fig 3D). The rock strength of different lithologies were measured semi-quantitatively using the in-situ geotechnical techniques. The rocks strength in the study area are in range from very weak to strong category (Fig. 3E). These make some localities easily erodible and some might be favourable for rockfall. All the thematic maps can be associated in multilayer framework that ultimately provides us the risk assessment for the road section (Fig. 4). The stereoplots for the structural attributes indicate the potential wedge failure is high in most of the sandstone dominating section of the road, rather than shale dominating sectors. The joint sets and slope stability plot can be used to understand the rock fall hazard potential. The plot clearly indicates unfavourable bedding conditions in most parts of the study area which frequently failed to cause rockfall and slide events. Critical failure area for wedge failure is shown by the red zone in the stereoplots. The plots were incorporated into the Risk assessment layer to correlate with each other (Fig. 4B). This reveals that the area is subjected to medium to high risk zone.

Conclusions

The Aizawl-Durtlang road section comprised of hard and compacted sandstone about 10m thick in some places are interbedded with shale and siltstone beds. Dark grey colour shale layers causes sliding in many areas. Silty sandstone and siltstone bands were found to be occurred in hill tops around few places. The bedding orientation is such that the area becomes unstable due to the topographic slope and other anthropogenic causes. Geological attributes in the study area is favourable for rock fall incidents as it is inferred by the geological map, profile and with different thematic DEM. The stereoplot of the bedding surfaces and the prominent joint surfaces indicate wedge failure characteristics of the rock beds. The bedding surfaces near Aizawl are much stable in such case and the risk increases towards half length of the section and then again show medium hazardous zone. The shale beds show higher frictional strength which left the arenaceous beds to topple down the slope. This study reveals that most part of the Aizawl Durtlang road section is vulnerable to rock fall cases and therefore authorities should take adequate measures to prevent any causalities from future events.

Figure 4: Risk Assessment for the Aizawl-Durtlang Road section. (A) Probable risk zones in the thematic layer map and some recent rockfall events in the area & (B) The Layer is superimposed in Google Earth image to understand most hazardous sections of the road. It also includes the wedge failure streoplot for different sections which imply the rock fall and slide probability.



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